



Contents lists available at ScienceDirect

## Sleep Medicine Reviews

journal homepage: [www.elsevier.com/locate/smr](http://www.elsevier.com/locate/smr)

## CLINICAL REVIEW

## Screen time and sleep among school-aged children and adolescents: A systematic literature review

Lauren Hale<sup>\*</sup>, Stanford Guan

Health Sciences Center, Level 3, Room 071, Stony Brook University, Stony Brook, NY 11794-8338, USA

## ARTICLE INFO

## Article history:

Received 11 June 2014

Received in revised form

20 July 2014

Accepted 29 July 2014

Available online xxx

## Keywords:

Sleep

Sleep duration

Total sleep time

Screen time

Media

Electronic media

Video games

Children and adolescents

## SUMMARY

We systematically examined and updated the scientific literature on the association between screen time (e.g., television, computers, video games, and mobile devices) and sleep outcomes among school-aged children and adolescents. We reviewed 67 studies published from 1999 to early 2014. We found that screen time is adversely associated with sleep outcomes (primarily shortened duration and delayed timing) in 90% of studies. Some of the results varied by type of screen exposure, age of participant, gender, and day of the week. While the evidence regarding the association between screen time and sleep is consistent, we discuss limitations of the current studies: 1) causal association not confirmed; 2) measurement error (of both screen time exposure and sleep measures); 3) limited data on simultaneous use of multiple screens, characteristics and content of screens used. Youth should be advised to limit or reduce screen time exposure, especially before or during bedtime hours to minimize any harmful effects of screen time on sleep and well-being. Future research should better account for the methodological limitations of the extant studies, and seek to better understand the magnitude and mechanisms of the association. These steps will help the development and implementation of policies or interventions related to screen time among youth.

© 2014 Elsevier Ltd. All rights reserved.

## Introduction

Insufficient sleep, delayed sleep-wake behavior, and sleep disturbances are common among youth and adolescents around the world [1]. For example, the 2011 Sleep in America Poll [2] reported that about 60% of adolescents in the United States (US) receive less than eight hours of sleep on school nights, which has increased from 45% in the 2006 Sleep in America Poll [3]. In addition, 77% of adolescents reported having sleep problems, with waking up feeling un-refreshed (59%) and difficulty falling asleep (42%) most commonly reported [2].

A review article [4] describes how delays in bedtime among youth as they get older can be attributed to biological, psychosocial, and environmental causes. One of these environmental sources is the use of screen-based activities that often delay bedtime or truncate total sleep time (TST). Nearly all US adolescents (97%) have at least one electronic item (e.g., television, computer, mobile phone, video game console) in their bedroom [3]. With the ubiquitous presence of media items in an adolescent's bedroom, screen time is hypothesized to be a cause of insufficient and low quality sleep [5], operating through several mechanisms [5,6]. The first is

time displacement – with more time in spent front of screens, youth have less time available to sleep. Second, psychological and physiological arousal due to the content of the media [7] and social interaction may also interfere with the ability to fall and stay asleep. And finally, there is the effect of light on both circadian rhythm and alertness. The effect on circadian rhythm is mediated through physiological suppression of the sleep-promoting hormone melatonin through the bright light from screens [8] and in the bedroom [9]. A recent study found that self-luminous tablets (Apple iPads set to full brightness) caused statistically significant melatonin suppression after two hours of use, but not from only one hour [10]. Additional research has shown that light has an acute alerting effect in which the dose, exposure duration, timing and wavelength of light evokes an alerting response among humans [11].

Electronic media pervade modern life. In the US, school-aged children and adolescents spend around 7 h per day in front of a screen [12,13]. The consequences of excessive screen time on general health, physical activity, cognitive and social development have been addressed by numerous scholars [14–17]. The effects of screen time on sleep patterns and sleep quality are also actively being studied by researchers around the world, but these findings have not been compiled in a systematic literature review in over four years [5]. In this review, we concisely update the only known prior systematic literature review that summarized the literature on the

<sup>\*</sup> Corresponding author. Tel.: +1 631 444 1007; fax: +1 631 444 3480.

E-mail address: [Lauren.hale@stonybrook.edu](mailto:Lauren.hale@stonybrook.edu) (L. Hale).

associations between screen time exposure and a range of sleep outcomes [5]. Further we highlight limitations of the current studies, leading us to conclude with recommendations for further research.

## Methods

We performed a systematic literature search in Web of Science for original scientific research publications about screen time and sleep. We used the following keywords to conduct our search “screen time AND sleep,” “media AND sleep,” “computer AND sleep,” “phone AND sleep,” “television AND sleep,” and “video game AND sleep.” On February, 24, 2014, 557 abstracts were returned. All were reviewed as to whether they met the inclusion/exclusion criteria discussed below. Additional searches in PubMed, Google Scholar, and various journals identified articles not duplicated in the original search. We also examined the cited literature in the included articles, and contacted three sleep experts to identify any missing articles. Two of the three experts responded and helped us identify nine additional articles. Based on these sources and after exclusions described below, the total number of original research articles included in the study is 67 [18–84]. Fig. 1 provides a flow chart of the studies included.

### Inclusion and exclusion criteria

We include all studies that investigate the association between any type of screen time and any of the following sleep outcomes: sleep timing, sleep duration, sleep quality, sleep onset latency (SOL), subjective assessment of daytime tiredness or daytime

sleepiness, or other reported outcomes including subjective assessment of insomnia symptoms. In order to be consistent with the prior literature review [5], we narrowed the articles down to include any study that contained participants that were primarily between five and 17 years old. We did not limit the population to any geographical area or gender. When data from the same cohort were presented in more than one study, we included only the most relevant article. We divided studies into type of media included (e.g., television, computer, mobile phone, video gaming device), allowing each study to be categorized in more than one media type, if appropriate.

This project updates a 2010 literature review [5] that used similar inclusion criteria. In the four years since publication of that paper, we found 31 additional articles meeting the inclusion criteria. All articles that fit the above criteria, including those in the 2010 review, are included in this review (See Table 1).

## Results

Table 1 provides an overview of the first author, publication year, and basic characteristics of all 67 articles included. Studies represent populations from around the world – most studies include samples from only one country and four studies cover multiple European countries at once. Over 40% (27 studies) of the samples used European populations. Twenty-one percent (14 studies) used US samples, 10% (seven studies) used Japanese samples, and 7% (five studies) relied upon Australian samples. The remaining studies included participants from Brazil, Canada, China, Israel, New Zealand, Saudi Arabia, and Taiwan.

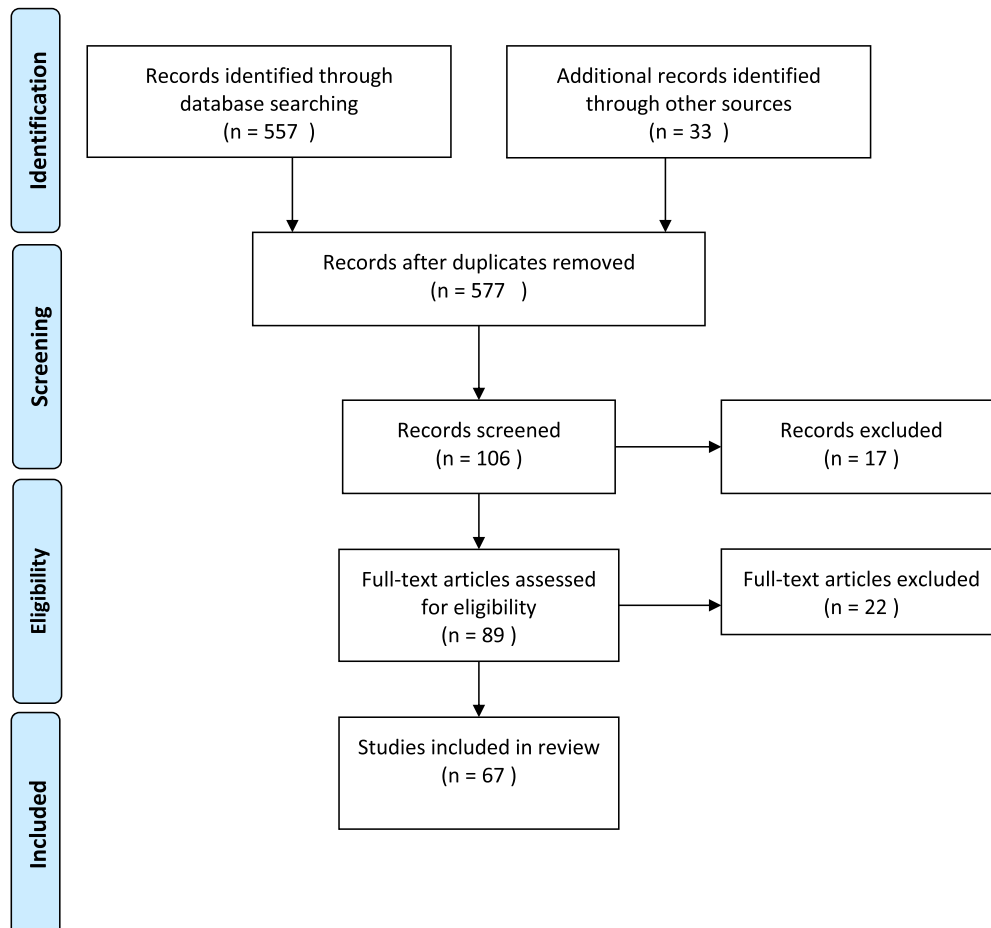


Fig. 1. Flow diagram.

**Table 1**

Summary of all studies that meet the inclusion criteria.

| First author         | Year | Region       | Sample size      | Age range (in years unless marked otherwise)            | Type of study                  |
|----------------------|------|--------------|------------------|---|--------------------------------|
| Abe [18]             | 2010 | Japan        | 1934             | 7th–9th grade   | Cross-sectional                |
| Adam [19]            | 2007 | US           | 2454             | 5–19  | Prospective (two random day)   |
| Arora [20]           | 2013 | UK           | 632              | 11–13   | Cross-sectional                |
| Arora [21]           | 2013 | UK           | 738              | 11–18   | Cross-sectional                |
| BaHammam [22]        | 2006 | Saudi Arabia | 1012             | 5–13  | Cross-sectional                |
| Barlett [23]         | 2011 | US           | 1317             |   | Prospective (13 mo)            |
| Calamaro [24]        | 2012 | US           | 625              | 6–10  | Cross-sectional                |
| Calamaro [25]        | 2009 | US           | 100              | 12–18   | Cross-sectional                |
| Cameron [26]         | 2012 | Europe       | 7234             | 10–12   | Cross-sectional                |
| Cespedes [27]        | 2014 | US           | 1864             | 6 mo (mean age at baseline followed annually); 3.2; 7.9 | Prospective (7 y)              |
| Chahal [28]          | 2012 | Canada       | 3398             | 10–11   | Cross-sectional                |
| Chen [29]            | 2006 | Taiwan       | 656              | 13–18   | Cross-sectional                |
| de Jong [30]         | 2013 | Netherlands  | 4072             | 4–13  | Cross-sectional                |
| Do [31]              | 2013 | South Korea  | 136,589          | 13–18   | Cross-sectional                |
| Drescher [32]        | 2011 | US           | 319              | 10–17   | Cross-sectional                |
| Dworak [33]          | 2007 | Germany      | 11 <sup>a</sup>  | 12–14   | Cross-sectional                |
| Eggermont [34]       | 2006 | Belgium      | 2546             | Mean ages 13.2 and 16.4 for 2 grade levels              | Cross-sectional                |
| Engelhardt [35]      | 2013 | US           | 128 <sup>a</sup> | 11–12   | Cross-sectional                |
| Foley [36]           | 2013 | New Zealand  | 2017             | 5–18  | Cross-sectional                |
| Fuligni [37]         | 2005 | US           | 750              | 14–15   | Prospective (2 wk)             |
| Gaina [38]           | 2006 | Japan        | 9718             | Mean age 12.8   | Cross-sectional                |
| Gaina [39]           | 2005 | Japan        | 699              | 12–15   | Cross-sectional                |
| Garaulet [40]        | 2011 | Europe       | 3311             | 12–18   | Cross-sectional                |
| Garmy [41]           | 2012 | Sweden       | 3011             | 6–16  | Cross-sectional                |
| Harada [42]          | 2002 | Japan        |                  | 13–15; 18–25  | Cross-sectional                |
| Heins [43]           | 2007 | Germany      | 1933             | 8–12  | Cross-sectional                |
| Hense [44]           | 2011 | Europe       | 8543             | 2–9   | Cross-sectional                |
| Hitze [45]           | 2009 | Germany      | 414              | 6–19  | Cross-sectional                |
| Ivarsson [47]        | 2013 | Sweden       | 30               | 13–16   | Cross-sectional                |
| Ivarsson [46]        | 2009 | Sweden       | 19 <sup>a</sup>  | 12–15   | Trial                          |
| Johnson [48]         | 2004 | US           | 759              | 14–22   | Prospective                    |
| King [49]            | 2014 | Australia    | 1287             | 12–18   | Cross-sectional                |
| King [50]            | 2013 | Australia    | 17               | 15–17   | Trial                          |
| Kubiszewski [51]     | 2013 | France       | 332              | Mean age 12.9   | Prospective (8 d)              |
| Lemola [52]          | 2011 | Europe       | 190              | 13–17 (subset, max age is 30)                           | Cross-sectional                |
| Li [53]              | 2010 | China        | 20,778           | 5–12  | Cross-sectional                |
| Li [54]              | 2007 | China        | 19,299           | 5–12  | Cross-sectional                |
| Magee [55]           | 2014 | Australia    | 3427             | 4–8   | Prospective (three waves, 5 y) |
| McKnight-Eily [56]   | 2011 | US           | 12,154           | 14–18   | Cross-sectional                |
| Mesquita [57]        | 2007 | Brazil       | 160              | 15–18   | Cross-sectional                |
| Mindell [58]         | 2009 | US           | 1473             | 0–10  | Cross-sectional                |
| Mistry [59]          | 2007 | US           | 3000+            | 0–5   | Prospective (5.5 y)            |
| Munezawa [60]        | 2011 | Japan        | 95,680           | 13–18   | Cross-sectional                |
| Nathan [61]          | 2013 | US           | 202              | 14–19   | Cross-sectional                |
| Nixon [62]           | 2008 | New Zealand  | 591              | 7   | Prospective (unclear how long) |
| Nuutinen [63]        | 2013 | Finland      | 353              | 10–11   | Prospective (18 mo)            |
| Oka [64]             | 2008 | Japan        | 509              | 6–12  | Cross-sectional                |
| Olds [65]            | 2012 | Australia    | 2200             | 9–16  | Cross-sectional                |
| Ortega [66]          | 2010 | Spain        | 2179             | 13–18.5   | Cross-sectional                |
| Owens [67]           | 1999 | US           | 495              | 5–10  | Cross-sectional                |
| Paavonen [68]        | 2005 | Finland      | 321              | 5–6   | Cross-sectional                |
| Padez [69]           | 2009 | Portugal     | 4511             | 7–9   | Cross-sectional                |
| Punamaki [70]        | 2007 | Finland      | 7292             | 12–18   | Cross-sectional                |
| Saarenpaa [71]       | 2001 | Finland      | 582              | 9–17  | Prospective (three waves, 3 y) |
| Seo [72]             | 2010 | South Korea  | 3639             | 7–12  | Cross-sectional                |
| Shochat [73]         | 2010 | Israel       | 470              | Mean age 14   | Cross-sectional                |
| Soderqvist [74]      | 2008 | Sweden       | 2000             | 15–19   | Cross-sectional                |
| Tazawa [75]          | 2001 | Japan        | 1143             | 6–11  | Cross-sectional                |
| Thorleifsdottir [76] | 2002 | Iceland      | 668              | 1–20  | Prospective (10 y)             |
| Van den Bulck [77]   | 2007 | Belgium      | 1656             | 13–16   | Prospective (1 y)              |
| Van den Bulck [78]   | 2004 | Belgium      | 2546             | 13–16   | Cross-sectional                |
| Van den Bulck [79]   | 2003 | Belgium      | 2546             | 13–16   | Cross-sectional                |
| Vazquez [80]         | 2008 | Spain        | 103              | 9–10.5  |                                |
| Wallenius [81]       | 2009 | Finland      | 4085             | 12–18   | Cross-sectional                |
| Weaver [82]          | 2010 | Australia    | 13 <sup>a</sup>  | 14–18   | Trial                          |
| Yen [83]             | 2008 | Taiwan       | 8004             | 12–18   | Cross-sectional                |
| Zhou [84]            | 2012 | China        | 1221             | 12–17   | Cross-sectional                |

<sup>a</sup> Males only.

**Table 2**

Summary of studies and their findings by sleep outcomes stratified by five definitions of screen time.

| First author   | STB  | Sleep outcomes |     |         |     |    |       |
|--|------|----------------|-----|---------|-----|----|-------|
|  |      | TST            | DBT | Quality | SOL | DT | Other |
| <b>2a. Television screen time and sleep outcomes</b> |      |                |     |         |     |    |       |
| Abe [18]   | No   |                | +   |         |     |    | *     |
| Adam [19]  | No   | X              | +   |         |     |    |       |
| Arora [20]   | Yes  | —              |     |         |     |    | *     |
| Arora [21]   | Yes  | —              |     |         |     |    |       |
| BaHammam [22]  | Yes  | —              |     |         |     |    |       |
| Calamaro [24]  | No   | 0              |     |         |     |    |       |
| Calamaro [25]  | Yes  | 0              |     |         |     |    |       |
| Cameron [26]   | No   | 0              |     |         |     |    |       |
| Cespedes [27]  | No   | —              |     |         |     |    |       |
| Chahal [28]  | Yes  | —              |     |         |     |    |       |
| Chen [29]  | No   |                |     |         |     |    | 0     |
| de Jong [30]   | No   | —              |     |         |     |    |       |
| Dworak [33]  | No   |                |     |         | 0   |    |       |
| Eggermont [34]                                       | Yes  | —              | X   |         |     | +  |       |
| Engelhardt [35]                                      | No   | 0              |     |         |     |    |       |
| Fuligni [37]   | No   | 0              |     |         |     |    |       |
| Gaina [38]   | No   |                |     |         | +   |    |       |
| Gaina [39]   | No   |                |     |         | 0   |    |       |
| Garaulet [40]  | No   | —              |     |         |     |    |       |
| Garmy [41]   | No   | —              |     |         |     |    |       |
| Heins [43]   | No   |                | +   |         |     |    |       |
| Johnson [48]   | No   |                |     |         |     |    | *     |
| Li [53]  | Both | —              |     |         |     |    |       |
| Li [54]  | No   | 0              | +   |         | +   | +  | *     |
| McKnight-Eily [56]                                   | No   | X              |     |         |     |    |       |
| Mindell [58]   | No   | —              |     |         | 0   |    | 0     |
| Mistry [59]  | No   |                |     |         |     |    | *     |
| Nixon [62]   | No   | 0              |     |         |     |    |       |
| Nuutinen [63]  | No   | X              | X   |         |     |    |       |
| Oka [64]   | Yes  | 0              | X   |         |     |    |       |
| Ortega [66]  | No   | X              |     |         |     | X  |       |
| Owens [67]   | Both | 0              |     |         | +   | 0  | *     |
| Paavonen [68]  | No   | —              |     |         |     |    |       |
| Padez [69]   | No   | —              |     |         |     |    |       |
| Saarenpaa [71]                                       | No   |                |     |         |     |    | *     |
| Seo [72]   | No   | —              |     |         |     |    |       |
| Shochat [73]   | Both | —              | +   |         | +   |    |       |
| Soderqvist [74]                                      | No   |                |     |         |     |    | 0     |
| Tazawa [75]  | No   |                |     |         |     |    | *     |
| Thorleifsdottir [76]                                 | Both | X              | +   |         |     |    |       |
| Van den Bulck [78]                                   | Both | X              | +   |         |     |    |       |
| Zhou [84]  | Both |                |     |         |     |    | *     |
| <b>2b. Computer screen time and sleep outcomes</b>   |      |                |     |         |     |    |       |
| Adam [19]  | No   | X              | +   |         |     |    |       |
| Arora [20]   | Yes  | —              |     |         |     |    | *     |
| Arora [21]   | Yes  | —              |     |         |     |    |       |
| BaHammam [22]  | Yes  | —              |     |         |     |    |       |
| Calamaro [25]  | Yes  | —              |     |         |     |    |       |
| Chahal [28]  | Yes  | —              |     |         |     |    |       |
| Chen [29]  | No   |                |     |         |     |    | 0     |
| de Jong [30]   | No   | —              |     |         |     |    |       |
| Do [31]  | No   | —              |     |         |     |    |       |
| Dworak [33]  | No   |                |     |         | +   |    |       |
| Eggermont [34]                                       | Yes  | —              | X   |         |     | +  |       |
| Engelhardt [35]                                      | No   | —              |     |         |     |    |       |
| Fuligni [37]   | No   | —              |     |         |     |    |       |
| Gaina [39]   | No   |                |     |         | 0   |    |       |
| Garmy [41]   | No   | —              |     |         |     |    |       |
| Heins [43]   | No   |                | +   |         |     |    | *     |
| King [49]  | No   | —              | +   |         | +   |    |       |
| Lemola [52]  | Yes  | —              |     |         |     | +  |       |
| Li [54]  | Both | —              |     |         |     |    | *     |
| Li [53]  | No   | —              | X   |         |     |    |       |
| McKnight-Eily [56]                                   | No   | —              |     |         |     |    |       |
| Mesquita [57]  | Yes  | —              |     |         | 0   | 0  |       |
| Nuutinen [63]  | No   | —              | +   |         |     |    |       |
| Oka [64]   | Yes  | X              | +   |         |     |    |       |
| Punamaki [70]  | No   |                |     |         |     |    | *     |
| Seo [72]   | No   | —              |     |         |     |    |       |
| Shochat [73]   | Both | —              | +   |         | 0   |    |       |

**Table 2 (continued)**

| First author  | STB  | Sleep outcomes |     |         |     |    |       |
|---|------|----------------|-----|---------|-----|----|-------|
|   |      | TST            | DBT | Quality | SOL | DT | Other |
| Van den Bulck [78]                                    | Both | X              | +   |         |     |    |       |
| Wallenius [81]  | No   |                |     |         |     | +  |       |
| Yen [83]  | No   | –              |     |         |     |    |       |
| Zhou [84]   | Both |                |     |         |     |    | *     |
| <b>2c. Video game screen time and sleep outcomes</b>  |      |                |     |         |     |    |       |
| Abe [18]  | No   |                | 0   |         |     |    |       |
| Adam [19]   | No   | X              | +   |         |     |    | *     |
| Arora [20]  | Yes  | –              |     |         | +   |    | *     |
| Arora [21]  | Yes  | –              |     |         |     |    |       |
| Chahal [28]   | Yes  | 0              |     |         |     |    |       |
| Engelhardt [35]                                       | No   | –              |     |         |     |    |       |
| Gaina [38]  | No   |                |     |         | +   |    |       |
| Heins [43]  | No   |                | +   |         |     |    |       |
| Ivarsson [47]   | Yes  | 0              | 0   | –       | 0   |    |       |
| Ivarsson [46]   | Yes  | 0              |     | 0       | 0   |    |       |
| King [49]   | No   | –              | +   |         |     |    | *     |
| King [50]   | Yes  | –              |     | 0       | +   |    |       |
| Lemola [52]   | No   | –              |     |         |     | +  |       |
| Nuutinen [63]   | No   | –              | +   |         |     |    |       |
| Oka [64]  | No   | –              | +   |         |     |    |       |
| Punamaki [70]   | No   |                |     |         |     |    | *     |
| Shochat [73]  | Both | –              | +   |         | 0   |    |       |
| Tazawa [75]   | No   |                |     |         |     |    | *     |
| Van den Bulck [78]                                    | Both | X              | +   |         |     |    |       |
| Wallenius [81]  | No   |                |     |         |     | +  |       |
| Weaver [82]   | Yes  |                |     |         | +   |    |       |
| <b>2d. Mobile devices and sleep outcomes</b>          |      |                |     |         |     |    |       |
| Arora [20]  | Yes  | –              |     |         |     |    |       |
| Arora [21]  | Yes  | –              |     |         |     |    | *     |
| Calamaro [24]   | No   | –              |     |         |     |    |       |
| Calamaro [25]   | Yes  | –              |     |         |     |    |       |
| Chahal [28]   | Yes  | 0              |     |         |     |    |       |
| Gaina [39]  | No   |                |     |         | 0   |    |       |
| Harada [42]   | Both | –              |     |         |     |    | *     |
| Heins [43]  | No   |                | +   |         |     |    |       |
| King [49]   | No   | –              | +   |         | +   |    | *     |
| Kubiszewski [51]                                      | Both |                | +   |         |     | +  | *     |
| Munezawa [60]   | Yes  | –              |     | –       |     | +  | *     |
| Nathan [61]   | Both |                |     |         |     | +  |       |
| Oka [64]  | Yes  | X              | +   |         |     |    | *     |
| Punamaki [70]   | No   |                |     |         |     |    | *     |
| Soderqvist [74]                                       | No   |                |     |         |     |    | 0     |
| Van den Bulck [79]                                    | Both |                |     |         |     | +  |       |
| Van den Bulck [77]                                    | Both |                |     |         |     | +  |       |
| Yen [83]  | No   | 0              |     |         |     |    | 0     |
| <b>2e. Unspecified screen time and sleep outcomes</b> |      |                |     |         |     |    |       |
| Barlett [23]  | Both | –              |     |         |     |    |       |
| Calamaro [24]   | No   | –              |     |         |     |    |       |
| Drescher [32]   | No   | X              |     |         |     |    |       |
| Foley [36]  | No   |                |     |         | +   |    |       |
| Hense [44]  | No   | 0              |     |         |     |    |       |
| Hitze [45]  | No   | –              |     |         |     |    |       |
| King [49]   | No   | –              | +   |         |     |    | *     |
| Kubiszewski [51]                                      | Both |                |     |         |     |    | *     |
| Magee [55]  | No   | –              |     |         |     |    |       |
| Olds [65]   | No   | –              | +   |         |     |    |       |
| Vazquez [80]  | No   | –              |     |         |     |    |       |

Note: STB – Whether screen time is measured at bedtime ('Both' indicating nighttime as well as general measurement); TST – Duration of sleep; DBT – Delayed bedtime; SOL – Sleep onset latency; DT – subjective assessment of daytime tiredness or daytime sleepiness; (0) – No association; (+) – Significant positive association; (–) – Significant negative association; (X) – Significant interaction. Other: Includes other sleep outcomes such as nighttime awakenings, subjective assessment of insomnia symptoms, irregular sleep, as well as researcher-defined sleep outcomes. \* $p < 0.05$ .

Table 2a–e divide the studies into screen type: 42 involved television media, 31 involved computer screens, 21 involved video game screens and 16 involved mobile device screens. There were 11 articles that categorized multiple types of screen into a single measure of screen time.

*Television watching and sleep*

**Table 2a** summarizes the studies involving television screens and television watching at bedtime; 32 out of 42 studies (76%) found an adverse association between television watching and adverse sleep outcomes, whereas 10 found no association.

Among the 32 articles that investigated the association between television watching and delayed bedtime or TST, 25 studies (78%) found that television watching was associated with significantly delayed bedtime or shortened TST. For studies that reported a significant negative association between television watching and sleep duration, higher levels of television screen watching was associated with either a larger effect size for shortened total sleep time or higher odds of short sleep duration.

Some of the studies had results with statistically significant associations between television and sleep only when stratified by certain variables. For example, television watching was associated with shorter sleep duration on weekdays compared to weekends [53,63,78]. Other studies found that older adolescents were more likely to have associations between television and later bedtimes compared to younger children [19,76]. Finally, male study participants were, in some studies, more likely than females to show an association between television watching and shorter sleep duration [56,66].

Of the studies that we coded as not reporting a significant association between television watching and TST, there are nuances worth discussing. Two studies [24,25] observed that television watching alone was not sufficient to significantly impact sleep (however, use of multiple screens did have a significant negative association with TST). One study [26] found that sleep duration did not mediate the association between the presence of a television in a bedroom and body weight. Another study [37] did not find an association between television watching and TST across individuals, but reported a positive daily-level association between these two measures within individual adolescents. The study author observed that adolescents watched more television on days where they studied less and were less stressed. These results were derived from a 14-d daily diary which is the longest daily diary prospective study that we catalogued (other studies that utilized a daily diary often used a 2-d daily diary or asked about sleep on a weekday and weekend (e.g., [72])).

Some studies found that television presence in the bedroom was associated with less sleep, even when reported use of television was not associated with less sleep [35,67]. The only study that relied upon objectively measured TST (using actigraphy) did not report a significant association between television watching and TST [62]. The lack of association in this study raises questions about the quality of self-reported and parental-reported sleep data.

Studies that estimated the magnitude of lost sleep time observed bedtime delays within the range of 5–10 min per hour of television watching [19,27,28]. These magnitudes can add up when one considers the total number of hours youth spend in front of a television [12,13]. Two separate studies, by the same lead author but on different samples, simply measured whether television watching occurred at bedtime (as a yes/no variable), and both found about a 20 min delay in sleep time [20,21].

The evidence for an association between television use and sleep onset latency (SOL) is equivocal: four of the seven studies that examined SOL found a significant association between television use and later sleep onset, while the other three studies reported no finding [33,39,58]. Several studies found an association between television watching and subjective assessment of daytime tiredness [34,54,66], while one study found no association [51]. Twelve studies included other measures of sleep outcomes and 75% of the studies found significant associations.

*Computer use and sleep*

**Table 2b** includes only the studies involving computer use. Twenty-nine out of 31 studies (94%) found an association between computer use and at least one of the sleep outcomes, while two found no association.

Our literature search yielded 24 scientific articles that specifically analyzed computer use and TST. All studies show shortened TST with computer use. In one study, the magnitude is 0.86 h (or 51 min) less TST for teens that report usually or always using the internet for social reasons at bedtime [20] than for teens who do not report using the internet at bedtime.

All of the nine studies that looked at delayed bedtime found that youth who use more computer screen time go to bed later. Five of the six studies (83%) that looked at sleep problems found that computer use predicted other sleep problems [20,33,51,83,84], whereas one study [52] did not find an association between computer use and other sleep problems. While no studies reported on the analysis of the association between computer use and general sleep quality specifically, three studies [34,52,81] (75% of 4) reported a significant association with subjective assessment of daytime tiredness or daytime sleepiness and only two out of five studies [33,49] reported a significant association with SOL. We also found that five out of the six studies that looked at “other” sleep outcomes found a significant association with computer use [20,43,54,70,84].

Comparing studies on computer use and sleep is difficult given the wide range of definitions and questions asked about computer time – for example, some asked about whether the computer was used for social networking, leisure, studying, or video gaming, while other studies grouped all computer use together. Nine of the studies specifically studied computer use at bed time [20–22,25,28,34,52,57,64], four of the studies asked about both daytime and bedtime use [53,73,78,84] and the remaining did not differentiate between timing of computer use.

*Video gaming and sleep*

**Table 2c** presents studies involving video game use. Among these, 18 out of 21 studies (86%) found an association between video games use and sleep patterns, while three found no association. All studies described in this section were included if study authors mentioned some form of screen-based game playing—which will henceforth be referred to as “video gaming.”

Among the 16 articles that examined video gaming and TST or delayed bedtime, 13 articles (81%) reported either a significant negative association with TST or a positive association with delayed bedtime. In several studies, significant results were moderated by age and day of the week. In one study, older study participants were more likely to have video game playing associated with later bedtimes [19]. In two studies, weekend video gaming was more likely to be associated with shorter sleep duration whereas this did not hold for weekday game playing [19,64]. Some studies estimated the magnitude of the sleep delay associated with bedtime video gaming as up to 28 min [20,21,28].

Of the three null findings: one study categorized video gaming as time spent at a game center/arcade [18], which is the only unconventional description of video gaming listed among these studies; and two studies examined low video game use as the unexposed group compared to high video game use [46,47], rather than comparing the high video game use to a no-use reference category.

For the outcomes of SOL and subjective assessment of daytime tiredness or daytime sleepiness, four out of seven studies (57%) reported a significant positive association between video gaming and higher SOL, while the two studies that looked at subjective assessment of daytime tiredness or daytime sleepiness found a significant



positive association with video gaming. Only three studies looked specifically at sleep quality: one found a significant negative association between video gaming and sleep quality [47], whereas two found no significant association [46,50]. Of the five studies that looked at other sleep outcomes, all of them found statistically significant associations with video gaming [19,20,49,51,75].

#### *Mobile devices and sleep*

Table 2d summarizes the studies involving mobile devices; among which 15 out of 18 studies (83%) found an association between mobile device use and at least one sleep outcome, while three studies found no association.

Of the 12 looking at TST or delayed bedtime, 10 (83%) found a statistically significant association between either shortened TST or delayed bedtime. Of the studies that estimated the amount to which sleep duration was shortened, one study of UK adolescents found that cell phone use at bedtime shortened sleep by 21 min [21] and another found that among pre-teens from the UK, usually using a mobile device at bedtime was associated with a shortened sleep duration of around 45 min [20]. Two studies failed to find the association between mobile phone use and sleep duration. The first collected data from Taiwanese adolescents and found that “problematic cell phone use” did not predict short sleep duration at the  $p < 0.05$  level, but the odds ratio (OR = 1.295, 95% CI 0.99–1.694) shows that the magnitude was reasonably large and was very close to reaching that level of significance [83]. The second study [28] found no significant association between use of a phone to chat or text at nighttime with sleep duration, but they did find a significant negative association between having a cellular phone (or other handheld communication device) in the student’s bedroom and TST. Two other studies that measured presence of a cell phone but did not measure its use found a significant association between having a cell phone in the bedroom and adverse sleep outcomes [24,43]. These and other findings on the effects of ownership or presence of devices are not included in the tables because we wanted to focus on use of the devices.

Two studies estimated the association between mobile phone use and SOL with one finding a positive association [49] and one finding no association [39]. This second study analyzed both mobile phone use ownership and SOL in a sample of Japanese schoolchildren in 2004 [39]. Given that mobile technology in 2004 was significantly different from the capabilities of modern smartphone technologies, there may be major differences in the impacts of mobile technologies on sleep between then and now. We speculate that this change in the technology utilization patterns over time may account for the differential in findings between the two studies.

Only one study investigated mobile phone use and sleep quality, and it found a negative association [60]. All five studies that investigated mobile phone use and subjective assessment of daytime tiredness or daytime sleepiness found an adverse association [51,60,61,77,79]. There were eight studies that looked at mobile devices and other sleep outcomes, of which six found significant associations [21,42,49,51,60,70], whereas two studies found no associations [74,83].

#### *Unspecified screen time and sleep*

Table 2e lists the 11 articles that clustered multiple types of screens into a single measure of screen time, which we term unspecified screen time. 91% of these found an adverse association between unspecified screen time and at least one of the sleep outcomes. All studies described in this section were included if study authors used an aggregate category of screen time and did not stratify by type of screen. Thus, while this category describes use of multiple screens, usage may not necessarily be simultaneous.

Among the nine articles that examined aggregate screen time and TST, eight articles (89%) reported a significant negative association with TST. Reported effect sizes range up to 45 min if multiple screens are present in a child’s bedroom [24]. One study [32] reported differential results by age group, where younger children under 13 y of age were more likely to have aggregate screen time associated with shorter sleep duration than older children, a finding in contrast to the stronger effects found among older teens for television viewing [19,76]. The study that reported a null finding [44] cited a limitation in aggregating screen time into one category.

Of the two remaining studies, one study [51] investigated screen time of middle-school aged children and found that evening screen time of one hour or more was associated with a 3.4-fold increased risk ( $p < 0.01$ ) of going to bed at 22:00 h or later. One other study [36] reported a significant association between aggregate screen use and later sleep onset.

#### **Summary and limitations**

Across all types of screens, we found that 90% of published studies show a significant adverse association with at least one of the measured sleep outcomes. Computer use (94% of studies), unspecified screen time (91% of studies), video games (86%), and mobile devices (83%) were most consistently observed to be associated with adverse sleep outcomes. The screen category that was least likely to have an adverse association with sleep outcomes was television use (76% of studies). This ranking is consistent with work hypothesizing that interactive screen time like computer use is more detrimental to sleep than passive screen time like television watching [82,85].

Despite these relatively strong and consistent results, we encountered numerous methodological challenges and limitations of all of the studies, as summarized below. A primary concern is that with the wide range of study populations, measurement challenges, and model specifications, there is a limited ability to harmonize the results and provide the magnitude and clinical significance of the association between screen time and sleep. Further, we have concerns about publication bias, in that scholars and journal editors often prioritize studies that show “significant” results rather than those presenting negative findings [86].

#### *Causality difficult to ascertain*

Given the use of observational data to study population behavioral patterns that occur among real-life children and adolescents, all but the three smallest of these studies [46,50,82] lack an experimental design in which one group is randomly assigned into a screen time exposure group while the other one has no screen time. As a result, while the rest of the studies provide a relatively good portrait of the screen time and sleep behaviors of youth, along with how these behaviors are associated statistically with each other in real populations, they do not provide enough data to confirm whether the association is causally linked.

There are several ways in which the observed associations may not indicate a causal impact of screen time on sleep outcomes. First, reverse causality might occur because youth who need less sleep or have trouble sleeping for other reasons choose to spend their time in front of more screens simply because they have more time to do so [34]. Further, there could be other confounding factors that are associated with both increased screen time and decreased sleep duration that suggest a spurious association. Examples of such potential confounding factors include having low physical activity and being overweight. However, there are ways to improve the likelihood of a causal link using observational data. The first is to have the measure of exposure (screen time) precede the

measurement of the outcome (sleep), such as using a daily diary over multiple days, as was done in only nine of the 67 studies [19,33,37,46,50,51,55,72,82]. This allows for screen time to be measured the day or night before sleep time and address some key issues of reverse causality. Another advisable approach to address causality is to adjust for as many potentially confounding variables as possible, provided the sample size allows for it. While most studies adjusted for basic covariates such as age and gender, several studies did an excellent job of adjusting for a wide range of characteristics including family structure [53], family income [53], sleep environment, physical activity, bedtime routine, and child health, among other variables [20,21]. Another approach would be to test for within-individual differences on nights when they do and do not have exposure to screen time, as was done in one study [37]. The gold standard would be to test the effects of an intervention or experiment that reduces screen time through random assignment as was done in the three trials included in our review [46,50,82].

#### *Measurement error*

The vast majority of the included studies (99%) rely upon either self-report or parental report for both the exposure and the outcome variables. Unfortunately, there has been very little research validating measures of self-reported and parent-reported screen time among youth. In addition, the sleep outcomes are also vulnerable to misreporting among teenagers, especially on more complicated concepts such as TST, night wakings, and SOL. For example, teenagers tend to overreport their total sleep time compared to actigraphic or daily diary measures of sleep [87]. One study [88] found that both adolescents and parents vastly underreported the presence of a sleep problem with accurate identification in only 33% and 17% of cases, respectively. Similarly, among school-aged children, a comparison of actigraphy data with parental report shows differing results, especially with regard to sleep quality measures [89]. In general, measurement error leads to attenuated associations [90]. Thus reducing measurement error in these studies will likely lead to a stronger and truer reflection of the association between screen time and sleep.

#### *Limited assessment of simultaneous screen exposure and other characteristics and content of screens*

While the vast majority of studies show an association between screen time and sleep outcomes, the measure of screen exposure varies by nature of the question. About 37% of the studies asked specifically about screen exposure in the hours before bedtime while the others asked for a more general use. Another limitation is that only one of the studies addressed whether multiple screens were being watched at once [25], and none investigated potentially important characteristics of the screens (i.e., size of screen, closeness to face, volume of device, etc.). Recent evidence [91] from an international survey of internet users reveals that nearly half of evening television watchers are also simultaneously engaged with other types of screens, such as a mobile device or computer. This trend of “screen-stacking” is expected to increase given the rapid growth of mobile technology. Content of the programming and interactivity of the user is also a topic that is understudied and requires further research. Understanding the characteristics of the screen utilization patterns that are most disruptive to sleep would be useful for developing policies and interventions that might minimize interference with wellbeing.

#### **Technological changes happening rapidly**

Finally given the rapidly changing screen-based technologies and utilization of devices, research on the effects of screen time on

sleep will likely be outpaced by the adoption of novel devices. This creates an even more urgent need to remain current on the latest technologies and their social, physical, and sleep consequences.

#### **Conclusions**

Despite the above limitations, given the large number of studies with consistent findings, we report that there is a significant association between screen time and reduced sleep duration and increased sleep problems, across a range of screen types and sleep outcomes in 90% of the studies. Future research should seek to better quantify and harmonize these findings so scholars have a better sense of the magnitude and clinical significance of the observed associations. While the research on understanding the causal link between screen time and sleep will need to be better addressed, it is important for parents, educators, policy makers, and scholars to work on designing, implementing, and evaluating messages and interventions that might reduce harmful forms and timing of screen exposure and analyzing the consequences for sleep and wellbeing for children and adolescents.

#### **Practice points**

- 1) Screen-based technologies are ubiquitous among modern youth and frequently used at bedtime; 90% of studies show an adverse association between screen time and sleep.
- 2) Youth should be advised to limit or reduce screen time exposure, especially before or during bedtime hours to minimize any harmful effects of screen time on sleep and well-being.
- 3) Current studies have various methodological limitations but the results are consistent across a wide range of studies from around the world.
- 4) Screen-based technologies and their utilization patterns are changing rapidly and require close attention to their lasting impacts on sleep and wellbeing.

#### **Research agenda**

- 1) This review documents the widely observed association between screen time and sleep; future emphasis should focus on the strength of this association and the clinical significance of the magnitude.
- 2) Research needs to better address the causal pathways between screen time and sleep.
- 3) Research should seek to replicate studies using more objective measures of both screen time and sleep; and when possible account for potentially important characteristics of screen time (i.e., timing, duration, screen size, volume, closeness to face, content) that can lead to behavioral changes.
- 4) The types and utilization patterns of screen-based technologies are rapidly changing, requiring ongoing monitoring and assessment of the potential impacts on youth behaviors.
- 5) Future research should develop and measure the impacts of public health messaging and interventions that seek to reduce youth screen time and their potential consequence on sleep, health, and wellbeing.

## Acknowledgments

This research is funded in part by National Institute of Diabetes and Digestive and Kidney Diseases and The Eunice Kennedy Shriver National Institute of Child Health and Human Development grants R21DK089414 and R01HD073352.

## References

- [1] Gradisar M, Gardner G, Dohnt H. Recent worldwide sleep patterns and problems during adolescence: a review and meta-analysis of age, region, and sleep. *Sleep Med* 2011;12(2):110–8.
- [2] Foundation NS. 2011 sleep in America poll [May 18, 2014]; 2011. Available from: [http://sleepfoundation.org/sites/default/files/sleepinamericapoll/SIAP\\_2011\\_Summary\\_of\\_Findings.pdf](http://sleepfoundation.org/sites/default/files/sleepinamericapoll/SIAP_2011_Summary_of_Findings.pdf).
- [3] Foundation NS. 2006 sleep in America poll [May 18, 2014]; 2006. Available from: [http://sleepfoundation.org/sites/default/files/2006\\_summary\\_of\\_findings.pdf](http://sleepfoundation.org/sites/default/files/2006_summary_of_findings.pdf).
- [4] Crowley SJ, Acebo C, Carskadon MA. Sleep, circadian rhythms, and delayed phase in adolescence. *Sleep Med* 2007 Sep;8(6):602–12.
- \*[5] Cain N, Gradisar M. Electronic media use and sleep in school-aged children and adolescents: a review. *Sleep Med* 2010 Sep;11(8):735–42.
- [6] Owens JA, Jones C. Parental knowledge of healthy sleep in young children: results of a primary care clinic survey. *J Dev Behav Pediatr* 2011 Jul–Aug;32(6):447–53.
- [7] Anderson CA, Bushman BJ. Effects of violent video games on aggressive behavior, aggressive cognition, aggressive affect, physiological arousal, and prosocial behavior: a meta-analytic review of the scientific literature. *Psychol Sci* 2001 Sep;12(5):353–9.
- [8] Higuchi S, Motohashi Y, Liu Y, Maeda A. Effects of playing a computer game using a bright display on presleep physiological variables, sleep latency, slow wave sleep and REM sleep. *J Sleep Res* 2005 Sep;14(3):267–73.
- [9] Gooley JJ, Chamberlain K, Smith KA, Khalsa SB, Rajaratnam SM, Van Reen E, et al. Exposure to room light before bedtime suppresses melatonin onset and shortens melatonin duration in humans. *J Clin Endocrinol Metab* 2011 Mar;96(3):E463–72.
- [10] Wood B, Rea MS, Plitnick B, Figueiro MG. Light level and duration of exposure determine the impact of self-luminous tablets on melatonin suppression. *Appl Ergon* 2013;44(2):237–40.
- [11] Cajochen C. Alerting effects of light. *Sleep Med Rev* 2007 Dec;11(6):453–64.
- [12] Rideout VJ, Foehr UG, Roberts DF. Generation M<sup>2</sup>: media in the lives of 8- to 18-year-olds. Menlo Park, CA: Kaiser Family Foundation; 2010.
- [13] Strasburger VC. Children, adolescents, obesity, and the media. *Pediatrics* 2011;128(1):201–8.
- [14] Iannotti RJ, Kogan MD, Janssen I, Boyce WF. Patterns of adolescent physical activity, screen-based media use, and positive and negative health indicators in the U.S. and Canada. *J Adolesc Health* 2009 May;44(5):493–9.
- [15] Must A, Tybor DJ. Physical activity and sedentary behavior: a review of longitudinal studies of weight and adiposity in youth. *Int J Obes (Lond)* 2005 Sep;29(Suppl. 2):S84–96.
- [16] Zimmerman FJ, Christakis DA. Children's television viewing and cognitive outcomes: a longitudinal analysis of national data. *Arch Pediatr Adolesc Med* 2005 Jul;159(7):619–25.
- [17] Steiner-Adair C, Barker T. The big disconnect: protecting childhood and family relationships in the digital age. 1st ed.
- [18] Abe T, Hagiwara A, Nobutomo K. Sleep patterns and impulse control among Japanese junior high school students. *J Adolesc* 2010;33(5):633–41.
- \*[19] Adam EK, Snell EK, Pendry P. Sleep timing and quantity in ecological and family context: a nationally representative time-diary study. *J Fam Psychol* 2007;21(1):4.
- \*[20] Arora T, Broglia E, Thomas GN, Taheri S. Associations between specific technologies and adolescent sleep quantity, sleep quality, and parasomnias. *Sleep Med* 2014;15(2):240–7.
- [21] Arora T, Hussain S, Lam KH, Yao GL, Thomas GN, Taheri S. Exploring the complex pathways among specific types of technology, self-reported sleep duration and body mass index in UK adolescents. *Int J Obes* 2013;37(9):1254–60.
- [22] BaHammam A, Bin Saeed A, Al-Faris E, Shaikh S. Sleep duration and its correlates in a sample of Saudi elementary school children. *Singap Med J* 2006;47(10):875.
- [23] Barlett ND, Gentile DA, Barlett CP, Eisenmann JC, Walsh DA. Sleep as a mediator of screen time effects on US Children's health outcomes. *J Child Media* 2011;6(1):37–50. 2012/02/01.
- [24] Calamaro CJ, Yang K, Ratcliffe S, Chasens ER. Wired at a young age: the effect of caffeine and technology on sleep duration and body mass index in school-aged children. *J Pediatric Health Care* 2012;26(4):276–82.
- \*[25] Calamaro CJ, Mason TB, Ratcliffe SJ. Adolescents living the 24/7 lifestyle: effects of caffeine and technology on sleep duration and daytime functioning. *Pediatrics* 2009;123(6):e1005–10.
- [26] Cameron A, Stralen M, Brug J, Salmon J, Bere E, ChinAPaw M, et al. Television in the bedroom and increased body weight: potential explanations for their relationship among European schoolchildren. *Pediatr Obes* 2013;8(2):130–41.
- \*[27] Cespedes EM, Gillman MW, Kleinman K, Rifas-Shiman SL, Redline S, Taveras EM. Television viewing, bedroom television, and sleep duration from infancy to mid-childhood. *Pediatrics* 2014;133(5):e1163–71.
- \*[28] Chahal H, Fung C, Kuhle S, Veugelers P. Availability and night-time use of electronic entertainment and communication devices are associated with short sleep duration and obesity among Canadian children. *Pediatr Obes* 2013;8(1):42–51.
- [29] Chen M-Y, Wang EK, Jeng Y-J. Adequate sleep among adolescents is positively associated with health status and health-related behaviors. *BMC Public Health* 2006;6(1):59.
- [30] De Jong E, Visscher T, HiraSing R, Heymans M, Seidell J, Renders C. Association between TV viewing, computer use and overweight, determinants and competing activities of screen time in 4-to 13-year-old children. *Int J Obes* 2013;37(1):47–53.
- [31] Do YK, Shin E, Bautista MA, Foo K. The associations between self-reported sleep duration and adolescent health outcomes: what is the role of time spent on Internet use? *Sleep Med* 2013;14(2):195–200.
- [32] Drescher AA, Goodwin JL, Silva GE, Quan SF. Caffeine and screen time in adolescence: associations with short sleep and obesity. *J Clin Sleep Med JCSM Official Publ Am Acad Sleep Med* 2011;7(4):337.
- [33] Dworak M, Schierl T, Bruns T, Strüder HK. Impact of singular excessive computer game and television exposure on sleep patterns and memory performance of school-aged children. *Pediatrics* 2007;120(5):978–85.
- [34] Eggermont S, Van den Bulck J. Nodding off or switching off? The use of popular media as a sleep aid in secondary-school children. *J Paediatr Child Health* 2006;42(7–8):428–33.
- [35] Engelhardt CR, Mazurek MO, Sohl K. Media use and sleep among boys with autism spectrum disorder, ADHD, or typical development. *Pediatrics* 2013;132(6):1081–9.
- [36] Foley LS, Maddison R, Jiang Y, Marsh S, Olds T, Ridley K. Presleep activities and time of sleep onset in children. *Pediatrics* 2013;131(2):276–82.
- \*[37] Fuligni AJ, Hardway C. Daily variation in adolescents' sleep, activities, and psychological well-being. *J Res Adolesc* 2006;16(3):353–78.
- [38] Gaina A, Sekine M, Hamanishi S, Chen X, Kanayama H, Yamagami T, et al. Epidemiological aspects of self-reported sleep onset latency in Japanese junior high school children. *J Sleep Res* 2006;15(3):266–75.
- [39] Gaina A, Sekine M, Kanayama H, Sengoku K, Yamagami T, Kagamimori S. Short-long sleep latency and associated factors in Japanese junior high school children. *Sleep Biological Rhythms* 2005;3(3):162–5.
- [40] Garaulet M, Ortega F, Ruiz J, Rey-Lopez J, Beghin L, Manios Y, et al. Short sleep duration is associated with increased obesity markers in European adolescents: effect of physical activity and dietary habits. The HELENA study. *Int J Obes* 2011;35(10):1308–17.
- [41] Garmy P, Nyberg P, Jakobsson U. Sleep and television and computer habits of Swedish school-age children. *J Sch Nurs* 2012;28(6):469–76.
- [42] Harada T, Morikuni M, Yoshii S, Yamashita Y, Takeuchi H. Usage of mobile phone in the evening or at night makes Japanese students evening-typed and night sleep uncomfortable. *Sleep Hypn* 2002;4(4):149–53.
- [43] Heins E, Seitz C, Schütz J, Toschke A, Harth K, Letzel S, et al. Bedtime, television and computer habits of primary school children in Germany. *Gesundheitswesen (Bundesverband der Ärzte des Öffentlichen Gesundheitsdienstes (Germany))* 2007;69(3):151–7.
- [44] Hense S, Barba G, Pohlabein H, De Henauw S, Marild S, Molnár D, et al. Factors that influence weekday sleep duration in European children. *Sleep* 2011;34(5):633.
- [45] Hitze B, Bosy-Westphal A, Bielfeldt F, Settler U, Plachta-Danielzik S, Pfeuffer M, et al. Determinants and impact of sleep duration in children and adolescents: data of the Kiel Obesity Prevention Study. *Eur J Clin Nutrition* 2009;63(6):739–46.
- [46] Ivarsson M, Anderson M, Åkerstedt T, Lindblad F. Playing a violent television game affects heart rate variability. *Acta Paediatr* 2009;98(1):166–72.
- [47] Ivarsson M, Anderson M, Åkerstedt T, Lindblad F. The effect of violent and nonviolent video games on heart rate variability, sleep, and emotions in adolescents with different violent gaming habits. *Psychosom Med* 2013;75(4):390–6.
- [48] Johnson JG, Cohen P, Kasen S, First MB, Brook JS. Association between television viewing and sleep problems during adolescence and early adulthood. *Archives Pediatrics Adolesc Med* 2004;158(6):562–8.
- [49] King DL, Delfabbro PH, Zwaans T, Kaptis D. Sleep interference effects of pathological electronic media use during adolescence. *Int J Ment Health Addict* 2013;1–15.
- [50] King DL, Gradisar M, Drummond A, Lovato N, Wessel J, Micic G, et al. The impact of prolonged violent video-gaming on adolescent sleep: an experimental study. *J Sleep Res* 2013;22(2):137–43.
- [51] Kubiszewski V, Fontaine R, Rusch E, Hazouard E. Association between electronic media use and sleep habits: an eight-day follow-up study. *Int J Adolesc Youth* 2013;1–13 [ahead-of-print].

\* The most important references are denoted by an asterisk.



- [52] Lemola S, Brand S, Vogler N, Perkinson-Gloor N, Allemand M, Grob A. Habitual computer game playing at night is related to depressive symptoms. *Personality Individ Differ* 2011;51(2):117–22.
- [53] Li S, Zhu S, Jin X, Yan C, Wu S, Jiang F, et al. Risk factors associated with short sleep duration among Chinese school-aged children. *Sleep Med* 2010;11(9):907–16.
- \*[54] Li S, Jin X, Wu S, Jiang F, Yan C, Shen X. The impact of media use on sleep patterns and sleep disorders among school-aged children in China. *Sleep* 2007;30(3):361.
- [55] Magee CA, Lee JK, Vella SA. Bidirectional relationships between sleep duration and screen time in early childhood. *JAMA Pediatr* 2014;168(5):465–70.
- [56] McKnight-Eily LR, Eaton DK, Lowry R, Croft JB, Presley-Cantrell L, Perry GS. Relationships between hours of sleep and health-risk behaviors in US adolescent students. *Prev Med* 2011;53(4):271–3.
- [57] Mesquita G, Reimão R. Nightly use of computer by adolescents: its effect on quality of sleep. *Arq Neuro-Psiquiatria* 2007;65(2B):428–32.
- [58] Mindell JA, Meltzer LJ, Carskadon MA, Chervin RD. Developmental aspects of sleep hygiene: findings from the 2004 National Sleep Foundation *Sleep in America Poll*. *Sleep Med* 2009;10(7):771–9.
- [59] Mistry KB, Minkovitz CS, Strobino DM, Borzekowski DL. Children's television exposure and behavioral and social outcomes at 5.5 years: does timing of exposure matter? *Pediatrics* 2007;120(4):762–9.
- [60] Munezawa T, Kaneita Y, Osaki Y, Kanda H, Minowa M, Suzuki K, et al. The association between use of mobile phones after lights out and sleep disturbances among Japanese adolescents: a nationwide cross-sectional survey. *Sleep* 2011;34(8):1013.
- [61] Nathan N, Zeitzer J. A survey study of the association between mobile phone use and daytime sleepiness in California high school students. *BMC Public Health* 2013;13(1):840.
- \*[62] Nixon GM, Thompson JM, Han DY, Becroft DM, Clark PM, Robinson E, et al. Short sleep duration in middle childhood: risk factors and consequences. *Sleep* 2008;31(1):71.
- [63] Nuutinen T, Ray C, Roos E. Do computer use, TV viewing, and the presence of the media in the bedroom predict school-aged children's sleep habits in a longitudinal study. *BMC Public Health* 2013;13(1):684.
- [64] Oka Y, Suzuki S, Inoue Y. Bedtime activities, sleep environment, and sleep/wake patterns of Japanese elementary school children. *Behav Sleep Med* 2008;6(4):220–33.
- [65] Olds TS, Maher CA, Matricciani L. Sleep duration or bedtime? Exploring the relationship between sleep habits and weight status and activity patterns. *Sleep* 2011;34(10):1299.
- [66] Ortega FB, Chillón P, Ruiz JR, Delgado M, Albers U, Álvarez-Granda JL, et al. Sleep patterns in Spanish adolescents: associations with TV watching and leisure-time physical activity. *Eur J Appl Physiol* 2010;110(3):563–73.
- [67] Owens J, Maxim R, McGuinn M, Nobile C, Msall M, Alario A. Television-viewing habits and sleep disturbance in school children. *Pediatrics* 1999;104(3):e27.
- [68] Paavonen EJ, Pennoen M, Roine M, Valkonen S, Lahikainen AR. TV exposure associated with sleep disturbances in 5-to 6-year-old children. *J Sleep Res* 2006;15(2):154–61.
- [69] Padez C, Mourao I, Moreira P, Rosado V. Long sleep duration and childhood overweight/obesity and body fat. *Am J Hum Biol* 2009;21(3):371–6.
- [70] Punamäki R-L, Wallenius M, Nygård C-H, Saarni L, Rimpelä A. Use of information and communication technology (ICT) and perceived health in adolescence: the role of sleeping habits and waking-time tiredness. *J Adolesc* 2007;30(4):569–85.
- [71] Saarenpää-Heikkilä O, Laippala P, Koivikko M. Subjective daytime sleepiness and its predictors in Finnish adolescents in an interview study. *Acta Paediatr* 2001;90(5):552–7.
- [72] Seo WS, Sung H-M, Lee JH, Koo BH, Kim MJ, Kim SY, et al. Sleep patterns and their age-related changes in elementary-school children. *Sleep Med* 2010;11(6):569–75.
- [73] Shochat T, Flint-Bretler O, Tzischinsky O. Sleep patterns, electronic media exposure and daytime sleep-related behaviours among Israeli adolescents. *Acta Paediatr* 2010;99(9):1396–400.
- [74] Söderqvist F, Carlberg M, Hardell L. Use of wireless telephones and self-reported health symptoms: a population-based study among Swedish adolescents aged 15–19 years. *Environ Health* 2008;7(1):18.
- [75] Tazawa Y, Okada K. Physical signs associated with excessive television-game playing and sleep deprivation. *Pediatr Int* 2001;43(6):647–50.
- [76] Thorleifsdottir B, Björnsson J, Benediktsdottir B, Gislason T, Kristbjarnarson H. Sleep and sleep habits from childhood to young adulthood over a 10-year period. *J Psychosomatic Res* 2002;53(1):529–37.
- [77] Van den Bulck J. Adolescent use of mobile phones for calling and for sending text messages after lights out: results from a prospective cohort study with a one-year follow-up. *Sleep* 2007;30(9):1220.
- \*[78] Van den Bulck J. Television viewing, computer game playing, and Internet use and self-reported time to bed and time out of bed in secondary-school children. *Sleep* 2004;27(1):101–4.
- [79] Van den Bulck J. Text messaging as a cause of sleep interruption in adolescents, evidence from a cross-sectional study. *J Sleep Res* 2003;12(3):263.
- [80] Vázquez IA, Zapico RB, Díez JH, Rodríguez CF. Actividad física, ocio sedentario, falta de sueño y sobrepeso infantil. *Psicothema* 2008;20(4).
- [81] Wallenius M, Rimpelä A, Punamäki R-L, Lintonen T. Digital game playing motives among adolescents: relations to parent–child communication, school performance, sleeping habits, and perceived health. *J Appl Dev Psychol* 2009;30(4):463–74.
- [82] Weaver E, Gradisar M, Dohnt H, Lovato N, Douglas P. The effect of presleep video-game playing on adolescent sleep. *J Clin Sleep Med JCSM Official Publ Am Acad Sleep Med* 2010;6(2):184.
- [83] Yen C-F, Ko C-H, Yen J-Y, Cheng C-P. The multidimensional correlates associated with short nocturnal sleep duration and subjective insomnia among Taiwanese adolescents. *Sleep* 2008;31(11):1515.
- [84] Zhou HQ, Shi WB, Wang XF, Yao M, Cheng GY, Chen PY, et al. An epidemiological study of sleep quality in adolescents in South China: a school-based study. *Child Care Health Dev* 2012;38(4):581–7.
- [85] Gradisar M, Wolfson AR, Harvey AG, Hale L, Rosenberg R, Czeisler CA. The sleep and technology use of Americans: findings from the National Sleep Foundation's 2011 Sleep in America poll. *J Clin Sleep Med* 2013;9(12):1291–9.
- [86] Stern JM, Simes RJ. Publication bias: evidence of delayed publication in a cohort study of clinical research projects. *BMJ* 1997 Sep 13;315(7109):640–5.
- [87] Wolfson AR, Carskadon MA, Acebo C, Seifer R, Fallone G, Lubyak SE, et al. Evidence for the validity of a sleep habits survey for adolescents. *Sleep* 2003 Mar 15;26(2):213–6.
- [88] Short MA, Gradisar M, Gill J, Camfferman D. Identifying adolescent sleep problems. *PLoS One* 2013;8(9):e75301.
- [89] Holley S, Hill CM, Stevenson J. A comparison of actigraphy and parental report of sleep habits in typically developing children aged 6 to 11 years. *Behav Sleep Med* 2010;8(1):16–27.
- [90] Hutcheon JA, Chiolerio A, Hanley JA. Random measurement error and regression dilution bias. *BMJ* 2010;340:c2289.
- [91] TNS. TV strikes back: rise of digital devices drives new viewing habits [7/17/2014]; 2014. Available from, <http://www.tnsglobal.com/press-release/connected-life-tv-press-release>.